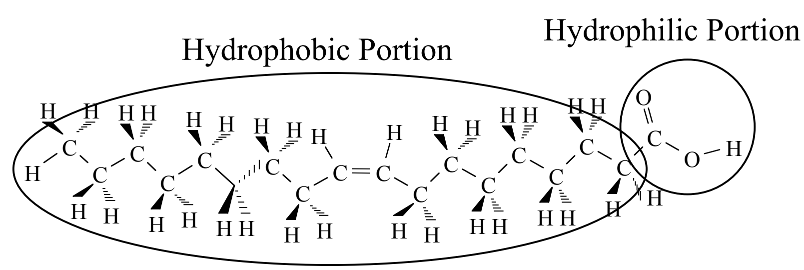
Dimension of a Molecule

Abstract: In this experiment we will do something remarkable. In a 10 minute experiment, we will determine the size of a single molecule! This is done by measuring the size of a film of fatty acid (oleic acid) on the surface of water. Once we know the size of the molecule, we can determine how many molecules are in a sample. We will actually be able to count molecules, a formidable task. We will also, by making a few assumptions, count the number of human scalp oil molecules that leave our skin when in contact with water.

Introduction: The experiment you are about to do has a long and interesting history. It was first done by Benjamin Franklin, who, in 1765, spread a known amount of olive oil on a pond at Clapham Common in London. From the area that the olive oil covered, he was able to estimate that the film had a thickness of no more than 10^{-7} inches. Experiments like this also allowed biologists to better understand the nature of the cell membrane (which isolates cells from their environment), and to actually determine the surface area covered by the cell membrane. In this laboratory we will determine the length of an oleic acid molecule. Olive oil, cell membranes and fatty acids such as oleic acid all belong to an unusual class of molecule, which is described below.



Oleic Acid

Oleic acid (see diagram), olive oil and the molecules which make up cell membranes have dramatically different parts. Each of these molecules consists of a "water loving" (hydrophilic) or polar portion **and** a "water fearing" (hydrophobic) or nonpolar portion. This class of molecules is known as "amphiphilic." When added to water, they spread out on the surface in a layer that is one molecule thick (a monolayer), with the hydrophilic portion bound to the water surface, and the hydrophobic portion pointed away from the water. The area covered by the molecules can be made visible if the water is covered with a fine powder, like lycopodium powder or pepper, which will not cover the surface occupied by the oil. It is interesting to note that a small drop of an amphiphilic substance will cover the surface of an olympic swimming pool, but oils that are entirely hydrophobic (like motor oil) do not spread out much at all in comparison. Soap molecules, like oleic acid molecules, are amphiphilic, and you may want to try an experiment like the one below at home using pepper in place of lycopodium powder, and dish detergent in place of oleic acid.

Procedure:
1) Wash a tray with soap, and rinse it thoroughly under a stream of water. Fill the tray with water to a depth of about 1 cm. Allow the water to become calm while performing step 2, then **lightly** dust the surface with finely ground white pepper.

2) Using a pasteur pipette, determine the volume of one drop of ethyl alcohol from your dropper by counting the number of drops that it takes to fill a graduated cylinder to the 1 mL mark. Make sure you hold the eye dropper upright so it dispenses the same size drop every time.

# of drops that constitute 1 mL _________________

3) Place one drop of ethyl alcohol on the dusted surface and observe. Describe what you see.

4) Place one drop of 0.125 (v/v)% oleic acid solution on the dusted surface and observe. Describe what you see.

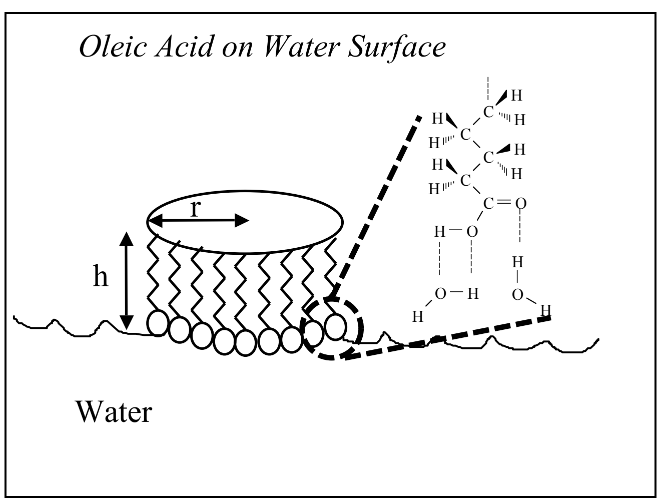
After the system has stabilized measure the diameter of the circle that is powder-free. Add drops one at a time until the diameter is about 8 cm. Record the number of drops that you used. (Does the same thing happen if the drop is released underwater, or from varying heights above the water?)

# of drops ___________ Diameter of circle _____________ cm

5) Prepare a fresh tray of dusted water. This time scratch your head with your fingers to transfer some of the oils from your scalp to the tip of your finger. Touch your finger to the dusted surface of the water for about 1 second. Measure the diameter of the circle.

Diameter of circle _________ cm

Calculations: By measuring the circular area obtained when a drop of alcohol containing 0.125 (v/v)% oleic acid is added to the dusted surface of water in a tray, we can determine the length of oleic acid as follows. We assume the circle that we see is really the top face of a cylinder whose height is equal to the length of oleic acid (see diagram). We can calculate the area of the circular face by using the formula $A = \pi r^2$ ($\pi = 3.1416$). We also know that the volume of the cylinder is equal to the height multiplied by the area of the face: $V = A \times h$. If we



could determine the volume of molecules in the cylinder, we could calculate their height, since we know the area.

The volume of the cylinder filled with molecules is determined as follows. First, one must determine the volume of solution added to the water surface. For example, if it took 40 drops to fill a graduated cylinder to the 1 ml mark, then the volume of 1 drop is 1/40 mL, or 0.025 mL. Now this drop that we placed on the surface was only 0.125% oleic acid. Therefore, in this case the volume of oleic acid alone that is contained in one drop of solution is: 0.025 mL x 0.00125 = 0.00003125 mL (where 0.125% has been expressed as the cardinal number 0.00125). Now the height of the cylinder can be calculated by dividing the volume (in mL, or cm^3) by the area (in cm^2).

Worksheet: (Refer to the previous two paragraphs on how to perform the following calculations)

1. What is the volume of 1 drop of oleic acid solution?

2. What volume of oleic acid is in 1 drop of solution, and therefore constitutes the powder-free layer on the water surface?

    If you used more than one drop, what is the volume of oleic acid that you added to the water surface?

3. What is the area of the oleic acid layer?

4. The powder-free layer is actually a very wide, short cylinder. The height of the cylinder is that of one molecule. For a cylinder V = h x A. Calculate the height of the cylinder (the length of the oleic acid molecule).

5. Assuming oleic acid is a cube so that the length, height and width are equal, calculate the volume of one molecule.

6. How many molecules of oleic acid are on the water surface.

7. Calculation of the number of scalp oil molecules which left your skin when in contact with water.

a. First, determine the volume of scalp oil molecules on the surface of the water. Assume that the scalp oil molecules are the same height as oleic acid (question 4).

b. Determine how many molecules are on the water surface. Assume that the scalp oil molecules have the same volume as oleic acid (question 5).

c. Think about how many molecules were evacuated from your finger in about 1 second. If all those molecules on your finger were people, how many New York Cities would this correspond to? The population of New York City is 8.927 million according to the 2000 census.

<u>Materials List:</u>

Large Pans (windows or pizza trays)
White Pepper
0.125% Oleic Acid
95% Ethanol
Rulers
10-mL graduated cylinders
Long-tipped Disposable Pipettes
(drops from short-tipped pipettes are too large for the pans we use)
Ethanol rinse for pipettes (if pipettes are rinsed at the end of the lab, reuse is possible)